

LASERS

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Laser systems of various configurations developed in this country during the past several years are currently being displayed in Exhibition Pavillions of USSR National Economy Achievements.

These exhibits permit one to evaluate, to a certain degree, those new devices which have been adapted to research as well as to technological and industrial fields. Among them are to be found lasers which operate on the basis of a stimulated emission of light.

Emission of the first, simple-frequency lasers (monochromatic frequency), took place in 1960 several years after the first emission of masers (low noise microwaves). Masers successfully combine the following properties: sensitivity, stability and linearity. Their application has, for the first time in the history of superhigh frequency (CBY) electronics, permitted the suppression of undesirable noises generated in receivers to the lowest minimal level at which the sensitivity allows external noises to be detected.

By the time lasers began to make inroads in the field of technology, masers had already acquired impressive successes. Thanks to masers it was possible to devise an accurate navigation system and to develop a super-precise clock whose margin of error is computed to be 1 second for every 300,000 years. Ammonia masers made it possible to carry out such intricate experiments, as for example the verification of Einstein's theory of relativity by installing them on board satellites of the "Cosmos" series.

Laser light amplification has found a variety of applications in radioastronomy, radar and lines of communication on earth and in space. Furthermore, they have also made it possible to increase ten-fold the sensitivity of receiver systems and have successfully been employed in the radaring of the planets Jupiter, Mars, Venus, Mercury and in the performance of other space experiments.

Paramagnetic amplifiers have been successfully applied for communications in space. They were instrumental in increasing tenfold the sensitivity of land-based receivers and by a similar amount improved the transmission of communications.

In order to reach these same results by means of an increase in the size of ground antennas, it would have incurred an incredible increase in the cost of the equipment--not to mention problems encountered in its construction.

While lasers have successfully been used in the USSR to communicate with ZOND-3 space station, which photographed the back of the moon, the U.S.A. is using them in the Telstar and Early Bird communications systems.

With the emergence of lasers, masers have taken a step to the side. Qualitatively, lasers are a newer development operating on a much shorter wavelength in the sub-multimeter and optical bands.

It is interesting to note that the transition from maser to laser did not take place as a result of a gradual and continued decrease in wavelengths intensified or generated by monochromatic oscillations but rather occurred as a leap from molecular oscillations equal to 1.25 cm to the wavelength of ruby lasers equal to 6.943×10^{-5} cm. Now then, how do lasers work and what are the principles behind their operation?

It is known that one of the most powerful heat sources of light is the sun. A total of 7×10^3 w/cm² of power is radiated in visible light from a single square centimeter of its surface. Thereupon on the sun there is 0.2 w/cm² at wavelength intervals of 0.1 angstrom. Ruby lasers pump $10^6 - 10^9$ w/cm² in this interval.

Solar radiation in principle cannot heat any body whatsoever above 6000°. The light radiation of gas-discharged lamps are more bright than the sun and can heat a body above 10,000°. But when that same lamp radiation, even though the energy losses are high, is converted into laser monochromatic emission with an energy spectral density billions of times greater than the initial density, qualitatively new potentials are achieved. Thus a ruby laser emission can heat a body to millions of degrees. The high concentration of light energy, achieved with lasers, is widely used in industry.

In an unusually short time, lasers have gone from the realm of the fantastic into a truly practical device; lasers have already "taken hold" in various jobs. Only recently the "KVANT-9," a unique laser device, was created, which is able to bore holes in diamonds without cracks or slips, something which could not be done to the challenge of hardness. However a new assembly, the "KVANT-10" has appeared, where a laser is used as a welder with almost unbelievable possibilities. At the speed of 50 mm/minute, a laser beam is "sewing together" parts made from quite different materials, and so densely that the welded seam does not permit passage of a single molecule into a vacuum "protected" by it. Incidentally this is referred to as vacuum-dense weld. It is precisely this strength of welding that is necessary in the production of semiconductor and electronic-vacuum devices, in fine instrument building, microelectronics; radio engineering and computer technology. So much the better since the characteristic of the laser beam -- an "impact" at a point with an insignificant diameter -- creates a minimum zone of thermal effect on the neighboring sections of the welded articles, thereby lowering the danger of their deformation.

It is known that it is difficult to cut, on an even line, sheet glass. A low-powered laser, mounted on an assembly for cutting contour glass, does this at a speed of 3.5 meters a second, making a cutting line as "fine as a thread." This "glass cutter" is completely automatic and stable in operation. It is equipped with two lasers in a gas mixture based

on carbon dioxide, CO₂, with a continuous power of 25 watts each and with two mobile focusing systems traveling in one plane along the cutting direction. This design allows cutting on two opposite planes of the contour glass in the form of a rectangular box, a channel, or wavy cross section and also to cut glass sheet in a continuous production process.

At the Exhibition one can see a laser device for engraving, used to make non-metallic typographic designs. Its use has increased the productivity of the technological process by a factor of five.

Multimetric length, a basic feature of the most powerful gas lasers, offers the possibility of making light "needles" of their beams up to that gigantic power, thanks to which even titanium plates can be cut easily. However this length appears to be their main disadvantage; try to "add" onto the dimensions of a modern machine the multimetric column of a laser assembly. At the Exhibit there is shown a mock-up of a coordinate-milling machine created on the basis of a gas laser with an original design solution. The machine's compactness is achieved by the fact that the range of the laser column is mounted on bends, like a folding pocket meter, and in the "bends" are placed the optical prisms which turn the beam in the direction necessary. A powerful laser is added in this machine, which is automatically controlled -- a numerical controlled program. The effect of using laser technology is such that the production volume per unit of productive power is increased fivefold.

Three medals and two honored diplomas from the Exhibition are the "trophies" of the laser semi-automatic installation created at the Moscow Aviation Technological Institute. In one minute this semi-automatic installation burns 60 holes measuring from 0.001 to 0.5 mm in diameter through any material up to 1 mm thick with the surface neatness of a machine from the eighth to the tenth class. In order to reset the semi-automatic installation to another diameter, it is sufficient to replace the lens and to focus the beam. A microscope mounted in the installation offers the possibility to control the quality of the parts obtained directly during processing. The turning of the coordinate bench with the article mounted to it, triggering of the laser, synchronization of all these processes, and separation of the installation after processing are automated.

In modern machines and equipment used for various purposes these many rapid-turning parts, the rotating axis, should absolutely pass through the center of gravity of the part and line up accurately with the main inertial axis. Otherwise large centrifugal forces appear and, as a consequence of this, vibration which wears out the bearings. In such a case it is not possible to calculate the durability, accuracy and high quality of operation of the machine. That is why the accuracy of part processing is so important.

When there is unbalance, the metal of the part must be removed actually in millimeters. A worker with many years of experience and with some flair for sensing the limit of this operation, spends about a half hour for only part in balancing and if he is "unlucky," he can waste the entire

shift. The attempt to remove the metal by the electrical method has not yielded, as a matter of fact, appreciable results -- high frequency currents frequently have sent the part directly into the waste. If the part is made from a ceramic or other non-conducting material, this method is altogether unsuitable. The laser assembly can cope with the balancing in one or two minutes. It consists of a balancing machine, two quantum generators, a synchronizer and a light pulse power regulator.

An indicator block notes during the rotation of the part the place of unbalance; the regulator determines the necessary energy and the synchronizer "finds" the right moment for the shock from the two light beams, instantaneously vaporizing the excess metal. This installation is designed for balancing the rotors of gyroscopes, electric shavers, and other items of equipment.

There are gas lasers excited by electrical discharges. They operate in a very wide range of frequencies -- from ultraviolet radiation to infrared radiation. At the present time neon-helium lasers continuously acting at 6328 \AA (red light) are very widely used. With its use light vibrations of very high stability and monochromaticity have been obtained. Although the efficiency and power of such lasers are extremely small, the high degree of monochromaticity and emission direction have made them irreplaceable for all kinds of alignment and levelling operations in laying out underground tunnels, strengthening the takeoff and landing fields of large airports and so forth. Thus a laser beam mounted at the entrance of a tunnel, with a sniper's accuracy, strikes the matrix of light photo sensors mounted in the tailing and cutting sections of the heading machine. Such high accuracy is ensured by the tracking system of the receiving device. It shows on the beam the matrices of the photo sensors as targets, regardless of the position of the heading machine. Deviations from the course laid out by the laser beam show up at once on the control indicator. There remains only the planning of the movement of the heading machine and the position of its axis along the direction of the light beam.

The equipment of the automatic control system using the modulated beam of a laser has been called the "navigator" of the underground roads. It provides a continuous and accurate recording of the movement of the heading machine and the possibility for the operating correction of the direction. This not only increases the speed of cutting, the quality of the mounting is considerably increased, the safest working conditions on the heading machine are created, and the number of servicing personnel is reduced.

Statistical data show that atmospheric sounding with a laser is a very promising method for its use. The idea is quite simple. The pulse of directed laser emission encounters gas molecules, capable of absorbing its energy, and atmospheric aerosol particles which scatter its light. By recording the reflection of the pulse with special equipment and by interpreting the record of the returned signal, one can determine the concentration and dimension of the particles. A ruby laser is used most frequently for such purposes. A description of one of these devices is given at the "Hydrometeorological" pavillion at the National Exhibition.

Measurement of the difference in frequencies of the original and reflected laser pulse permits the wind speed to be determined. If two laser pulses with close frequencies are used for sounding, one can measure the concentration of molecules of any atmospheric gas. Knowledge of the concentration, for example, of oxygen is equivalent to the determination of the general pressure. Generally, during laser sounding of the atmosphere can in principle obtain data on many characteristics of the atmosphere, which influence the meteorological processes.

Modern ruby lasers can emit pulses lasting several tens of nanoseconds (billion parts of a second) and with a power of hundreds of megawatts. Experiments have shown that the energy from one such pulse is sufficient to send a signal and record its reflection from an altitude of 30-40 kilometers. Does this mean that the laser "ceiling" is not higher than an aircrafts? No, it is possible to use a series of pulses and, having in this manner accumulated the energy reflected from high altitudes, to measure it.

At the disposal of scientists there are also lasers which are capable of importing even more powerful pulses and with greater frequency. A pulse lasting 10 nanoseconds, shooting through the atmosphere with the speed of light, can give, at each moment, yield information on the state of a column of air, several meters in diameter. This is fantastic accuracy for existing methods. No less important is the fact that laser sounding permits the determination of the value of any meteorological parameter along the entire course of the beam. One can obtain a practically continuous curve of data in a previously given direction of pulse propagation.

Sounding can be done vertically, obliquely and horizontally. Modern ruby lasers are capable of sending tens of pulses per second, which assures the study of the dynamics of rapidly occurring atmospheric processes, for example the northern polar scattering (aurora borealis). The data obtained by laser sounding arrive at the computer center practically instantaneously since the pulse travels with the speed of light. To process the results of measurements it is proposed to use high speed electronic computers, the information to which will arrive directly from the laser location.

The use of lasers for sounding the atmosphere, the surface of lands and oceans from orbital space stations opens up great prospects. Data on various meteorological features during cloud-free weather can be obtained with the help of a single pulse from an altitude of 300 kilometers. When clouds are present, their upper boundaries can be determined with great accuracy. Additionally, the reflected pulse permits the fixing of the cloud density, concentration and dimension of its particles.

Orbital space stations, equipped with laser locators provide scientists with the possibility to measure the height of various points on the earth's surface with an accuracy up to several tens of centimeters, to conduct the remote study of noctilucant clouds, and to determine the transparency of various water basins.

Laser locators have been created and successfully used for atmospheric soundings, which are called lidars. Many important studies have been made by using them. Lidars reliably detect aerosol layers and clouds in the atmosphere, invisible to the eye. The first data on the lower boundary and thickness of noctilucant clouds and on the distribution of moisture by altitude in lower atmospheric layers have been obtained. New equipment is being used to control atmospheric pollution from various aerosol impurities of industrial and natural origin.

In the pavillions of the Exhibition one can learn about the use of a gas laser for heating a plasma up to temperatures at which thermonuclear reactions occur, about laser installations for holographic research, about a laser apparatus for measuring local speeds in flows of fluids and gases, necessary in conducting hydrodynamic and aerodynamic research, and so forth. However one should especially note one of the most original and promising laser devices -- the laser television projector.

One of the most complex tasks confronting cyberneticists today is to program electronic computers to recognize shapes. If a machine can do this, then the information input processing time can be sharply reduced. The computer could "read a page" of any manuscript or printed text, line drawings and calculations. A device for holographic research and image recognition, developed by scientists at the Moscow Institute of Radio Engineering and Electronics is an important step on this path. Presently the device can already identify images. The laser beam passes through the image, put on roll film, and falls on the figure, line drawing or photograph which is compared with the image. In fractions of a second the beam compares them and answers whether they coincide or not.

Cybernetic scientists place great hope on the laser. On the basis of a holographic method it is possible to develop high-speed electronic computers, millions of times faster than the best modern machines. Their memory is increased over a thousand times. The device for holographic research and recognition of images, which is being demonstrated at the USSR Academy of Science's "Physics" pavillion is one of those holographic apparatuses in which the potentials of the laser beam are verified and studied.

Such, at the present time, are the fundamental directions in the development and application of lasers.